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CARBON BISULPHID AS AN INSECTICIDE.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Entomology,
Washington, D. C., November 26, 1901.

Sir: While Mr. W. E. Hinds was temporarily employed as an assistant in this Division during the summer of 1901 he was instructed to conduct certain practical experiments with the use of bisulphid of carbon against the cigarette beetle (*Lasioderma serricorne*) in a large wholesale and retail tobacco establishment in the city of Washington. The successful prosecution of this work made it necessary for Mr. Hinds to familiarize himself thoroughly with the subject, and it has seemed to me very desirable that the results of his studies should be formulated in a Farmers' Bulletin for the use of persons interested in the destruction of insects injurious to stored products, underground insects, household pests, museum pests, tree borers, and sucking insects on small plants. I have, therefore, instructed him to prepare such a bulletin, and I submit his manuscript with the recommendation that it be published as a Farmers' Bulletin.

I am indebted to Mr. E. E. Ewell, of the Bureau of Chemistry, for the purely chemical portion of this bulletin, which is printed as an appendix.

Respectfully,

L. O. Howard,
Entomologist.

Hon. James Wilson,
Secretary of Agriculture.

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CARBON BISULPHID AS AN INSECTICIDE.

INTRODUCTION.

It is the purpose to bring together in the following pages some of the principal facts concerning the use and effects of carbon bisulphid. During the years since it was first used as an insecticide many important facts have been established. Records of these facts are, however, so widely scattered that it has been difficult to bring enough of them together to obtain even a fair understanding of the nature and use of this substance. Moreover, many of the most important facts have been practically buried in the mass of French literature concerning the grape Phylloxera. The writer claims but little of this work as original; but many of the conclusions he has verified by his own experiments, and the data furnished by the Bureau of Chemistry are almost wholly new. The chemical side of the subject has been treated in an appendix, in order that those desiring to do so may easily inform themselves as to the properties and behavior of the liquid which they may handle.

PROPERTIES OF CARBON BISULPHID.

Carbon bisulphid is a colorless watery liquid, formed by the union of two elementary particles of sulphur with one of carbon (charcoal). Its chemical symbol is CS_2. It is made on a large scale by passing the fumes of burning sulphur over red-hot charcoal. The resulting vapors are condensed to a liquid form by cooling, and the impurities are removed therefrom.

LIQUID PROPERTIES.

The liquid is one-fourth heavier than water, its specific gravity being 1.29 at the freezing temperature of water. It is extremely refractive, so that when its surface is disturbed it reflects the light from the ripples much more strongly than does water. It is very volatile, evaporating with great rapidity when freely exposed to the air. The rapidity of evaporation depends mainly upon the area of the evaporating surface and the temperature of the liquid and the air. It may be retarded by mixing the liquid with various substances, and is wholly prevented by covering the surface of the carbon bisulphid with a layer of water, which, being lighter, floats easily on top just as

kerosene does upon water. The rapid evaporation of the liquid takes up a large amount of heat. If a little be poured upon the hand, a burning sensation will be experienced, which, however, is due, not to a burning, but to a cooling process, as may be perceived by touching the spot with the other hand. No harm need be feared from getting it upon the skin. When perfectly pure the liquid has an acrid taste and a rather sweetish, not unpleasant, ethereal odor, quite similar to that of ether or chloroform. Pure carbon bisulphid is completely volatile, and will not injure or stain the finest fabrics. Even when poured directly upon food stuffs their edibility is not at all impaired, and all trace of the odor disappears quickly upon free and full exposure to the air. The ordinary commercial article, however, has a slightly yellowish tinge due to its impurities, which also give it a rank fetid odor that is extremely obnoxious. These impurities add to its poisonous qualities. When the impure article is used, some slight residue may be left after the evaporation of the liquid. For this reason this grade will stain goods, and it should not be poured upon food stuffs, though its vapor will do them no harm. Liquid carbon bisulphid is not at all explosive, so there need be no fear of handling it, provided the cans are perfectly tight. It is best kept in an outhouse where there is no fire and where it is dry, so that the cans will not rust and allow the vapors to escape through leaks. The liquid boils at 115° F., but a few degrees higher than the temperature of the human body. One volume of the liquid is said to give 375 volumes of vapor upon evaporation.

VAPOR PROPERTIES.

The vapor of carbon bisulphid is 2.63 times as heavy as air, and can, therefore, be poured from one glass to another almost like water. It can be seen flowing down over the edge of an open vessel containing the liquid. Although it diffuses quite rapidly through the air, as can be perceived by its odor, it is evident that the vapor will always tend to work downward more strongly than upward and that it will always be more dense at the lower levels. This point should be borne in mind, as it has an important bearing upon the application of the bisulphid. The vapor, as well as the watery solution, is a powerful disinfectant. Meats will keep in an atmosphere of it for months without change. Lamps have been devised for burning carbon bisulphid in disinfection work, but, as the active disinfectant is the same gas as is formed by burning pure sulphur or brimstone, it can be obtained more cheaply in the latter way.

EFFECTS OF INHALATION OF THE VAPOR.

Concerning the effects of the inhalation of the vapor, we learn from chemical and medical works that the gas is highly poisonous, producing giddiness, vomiting, congestion, coma, and finally death. These

of course are its extreme effects. In the ordinary use of carbon bisulphid on a large scale, as in the fumigation of mills, warehouses, etc., where the worker may be more or less exposed to the inhalation of the fumes for some time, only those effects which precede giddiness are likely to be experienced. From his own experience and information obtained from others who have used carbon bisulphid in such work, the writer gleans the following as the effects preceding giddiness: The first appreciable effect is upon the sense of smell. At first the fumes have an extremely disagreeable odor, but this soon seems gradually to disappear, showing that the sense of smell becomes deadened. The other senses seem to become benumbed simultaneously, so that the operator does not realize that anything is the matter with him. The heart beat becomes more and more rapid as the oxygen in the lungs diminishes. The power of thought is very much weakened and the work is continued in a mechanical sort of way. Hearing and sight are also weakened. But before this weakening process has gone far enough to be really dangerous or injurious, the operator will probably feel more or less dizziness. There is no pain or disagreeable sensation; no desire to get out of it, and no sense of suffocation. But when a person has reached this condition it is high time to get out into the fresh air where the ill effects will quickly disappear. Owing to the effect of the gas upon the heart action, it may be well to caution persons having any trouble or weakness about the heart against taking any extended part in the application of the bisulphid. It should be clearly understood by those who use it that the action of the gas is somewhat poisoning as well as suffocating. Should the operator persist in remaining in the room after the dizziness comes on, he will be in danger of falling, and, if not discovered, he will soon suffocate. Even if he should get out safely, the ill effects will be more marked and a severe headache, at least, may ensue. If upon the approach of dizziness, the operator goes at once to a window, or better still out of doors, an abundance of fresh air will in a few minutes remove all ill effects, and no injury will result from the experience. The inhalation of the fumes can be somewhat retarded by tying a wet handkerchief tightly over the face. This, however, merely diminishes the amount of air taken into the lungs without affecting the proportion of vapor contained therein. When obliged to enter a room in which the air is charged with any considerable amount of the vapor, the writer makes use of the following simple device, which is perfectly effectual: A large paper bag (20 quarts or more) is tied tightly around a short piece of tubing of glass, rubber, or metal, inserted in its mouth. When infla ed, the bag contains sufficient air to enable one to respire into it for several minutes without discomfort. Being very light, it can be carried by the tube in the mouth, thus leaving the hands free for any work desired.

This point has been discussed rather fully, not because there is any particular danger or need for fear in handling this insecticide, but in order to lessen the fear of its use and to neutralize whatever danger there may be in its application by giving an intelligent understanding of the precise nature and effects of the chemical. When these are known, it can be handled with much greater safety and far less fear than is possible where the user knows there is danger, but does not know just what the danger is. The danger from its use is practically of the same kind as that from gasoline, which is in common use in thousands of homes. Really, the danger is very much less, since every precaution is taken to keep carbon bisulphid from the proximity of fire, while gasoline is used principally in connection with fire.

CARBON BISULPHID AS AN INSECTICIDE.

FIRST USE AS AN INSECTICIDE.

So far as the writer can learn, the first use of carbon bisulphid as an insecticide was made in 1856 and 1857 by M. Doyere, who demonstrated that a small amount of the liquid poured into a pit of corn or barley would kill all the weevils and their eggs; that this chemical agent did not alter at all the quality of the grain; that it left only a slight odor, which was not, however, persistent, but disappeared promptly upon the exposure of the grain to the free air. Since that time its use has steadily increased, and it is now generally recognized as one of the most useful insecticides.

APPLICABILITY TO VARIOUS INSECTS.

Carbon bisulphid is applicable to a large number of insect pests living under very different conditions, which, therefore, require different modes of application. These insects can be divided into groups, according to certain similarities of their habits of life or of their habitats. The members of each group have been found to be susceptible to practically the same mode of treatment with such minor variations as the individual life histories may require for greatest effectiveness. In a general way, we may say that carbon bisulphid is applicable only where its vapor can be more or less confined. Its field of usefulness is among those insects which can not be reached through poisoning their food and those that are very difficult to reach with contact insecticides by spraying. Such insects are found both indoors and out of doors, and the general methods of treatment in these two environments must necessarily vary considerably.

DIFFUSION OF THE VAPOR.

This vapor diffuses through the air very rapidly and must, therefore, be closely confined in order to maintain a sufficient proportion

of it in the atmosphere to prove fatal to insect life. It tends most strongly to spread outward and downward on account of its being so heavy, and, though it will gradually work upward, its greatest density will be at the lowest levels. The usual calculation is to employ one pound of liquid carbon bisulphid to each 1,000 cubic feet of space treated, whether for the treatment of insects in buildings or for insects in the ground. This amount gives an atmosphere, if confined to that space, composed approximately of 1 part in 90 of carbon bisulphid vapor, which, as we shall see, is a fatal strength in a short time. However, where the atmosphere can not be absolutely confined and there is considerable opportunity for the vapor to escape, it is frequently necessary to apply from two to four times that amount, under circumstances where there is no danger of killing plant life.

INSECTICIDAL POWER.

In 1876 two French investigators, Cornu and Mouillefert, performed a series of experiments to determine the insecticidal power of carbon bisulphid vapor. They were working primarily upon the grape Phylloxera, but, in addition to that insect, they experimented with caterpillars, butterflies, cicadas, wasps, and plant-lice. In a series of five large flasks they produced an atmosphere composed of 1 part of carbon bisulphid vapor to 12, 30, 60, 120, and 180 parts of air. Within each of these flasks grape roots bearing the Phylloxera were confined for twenty-four hours, at the end of which time the insects were dead in each case. In other experiments in which all of the previously mentioned insects were used it was found that in an atmosphere composed of 1 part carbon bisulphid vapor to 90 parts air, all insects perished in a few seconds, and that an atmosphere composed of 1 part of carbon bisulphid vapor to 254 parts of air was fatal in one and one-fourth hours. The same result is therefore attained by a small proportion of the vapor acting through a long time as by a large proportion acting for a short time.

HOW PUT UP AND COST.

Carbon bisulphid is put up in tight tin cans or iron drums holding from 1 to 50 pounds. It may be purchased in small quantities of any druggist, at from 25 to 35 cents per pound; but if any considerable quantity is to be used, it is much better to buy of some wholesale druggist, or, better still, direct from the manufacturers. In the latter way it is shipped in 50 pound cans or drums at 10 cents, or even less, per pound, with an additional charge for the drums, which are returnable at the purchase price; but all freight charges are paid by the buyer.

USES OF CARBON BISULPHID.

COMMERCIAL USES.

Carbon bisulphid is extensively used in the arts as a solvent for a number of things, such as sulphur, phosphorus, oils, resins, caoutchouc, gutta-percha, etc. It is largely used in rubber manufacture, being especially valuable in the manufacture of waterproof goods. In woolen manufacture it is used to regain oils and fats from the wool. The fact of its being so widely used shows that it is not an unusually dangerous thing to handle, though there can be no doubt that the long-continued inhalation of even a little of the fumes produces very bad effects upon the health of the operators.

PHYLLOXERA TREATMENT.

It is for insects living underground especially that this insecticide fills a need which has not yet been equally well met by any other. By far its largest use in insecticidal work has been in France against the grape Phylloxera—a little plant-louse living mainly upon the roots of that vine. This insect is a native of the United States, and from here was introduced into France about 1859 upon imported vines. As is the rule with insect pests, this plant-louse proved to be far more destructive to the vines in France than it had been in this country. In 1863 its first injuries were manifest, and in less than ten years it had multiplied so enormously there and spread so widely that it was feared that vine growing in France was doomed. This insect's connection with the deterioration and death of the vines was not known until 1868, when it was proven by a French scientist.

This insecticide was first applied to the Phylloxera in 1859 by Baron Paul Thénard. Unfortunately, in attempting to force the fumes to the necessary depth to kill the insects he also killed his vines by the overdose. Later experiments gave better results. In 1873 the use of carbon bisulphid rapidly increased until over 200,000 acres were receiving annual treatment. Treatment had to be repeated for three years before the vines regained their normal condition.

This use of carbon bisulphid for the Phylloxera was the beginning of its underground use. The following is a summary of the principal conclusions reached by many experimenters in the course of years of work against this little root louse:

Diffusion of the vapor in the soil.—Upon being introduced into the soil at some depth below the surface the liquid evaporates as it does in the open air, only much more slowly. The vapor tends to diffuse through all the air spaces of the soil. It thus produces an atmosphere which is fatal to all insects living within its reach. The rapidity of evaporation, the extent of diffusion, and the persistence of the vapor in the soil vary widely in soils of varying characters and conditions,

so no one rule of application can be employed in all cases, and it thus becomes necessary to understand the influence of various factors that proper allowance may be made for them and the destruction of the insects attained without injuring the plants.

Moisture.—Carbon bisulphid evaporates most rapidly in a warm, dry, sandy soil, and the persistence of the vapor is also shortest in such soil. In fact it diffuses so rapidly that most insects will survive an ordinary dose; and if the dose is increased so as to kill the insects, it is likely to kill the vines as well. The treatment can not be successfully applied on such a soil in its dry condition. On the other hand, diffusion is slowest in heavy, wet, clay soil; and, when such soil is saturated with water, it is almost entirely prevented. Moisture lowers the temperature and decreases the permeability of the soil; it also prevents the evaporation of the liquid, and thus retards diffusion. Between these two extremes there is a medium condition of moisture which is most favorable for treatment.

Character of soil.—Sandy soils permit an even but too rapid diffusion of the vapor. Rocky soils are not of even texture, and naturally the vapors follow the lines of least resistance. Heavy clay soils, when very dry, are usually much broken by cracks and fissures, which may run from the surface to a considerable depth. Through such fissures the vapor escapes rapidly without permeating the soil to any extent, and its insecticidal value is therefore slight. But when such a soil is well moistened it is even in texture and very favorable to treatment.

Depth of soil.—The depth of the soil is an important factor in determining how much carbon bisulphid must be used for a given area. If the soil is shallow and the subsoil very dense and impervious, it is evident that much less liquid will be required to produce a death atmosphere than will be needed in a soil of much greater depth. In soils of the same character and condition the amount needed will be proportional to the permeable depth of the soil. In heavy, compact soils increase the number of injections and diminish the dose; in light, deep, permeable soils decrease the number of holes and increase the dose.

Amount to use.—In field experiments with the grape, using plain carbon bisulphid in "quite fresh" soil, vines were found to withstand 105 c. c. of carbon bisulphid (4.4 ounces, nearly), divided equally among 3 holes placed about 16 inches from the base of the vine and at a depth of about 20 inches; but 180 c. c. (7½ ounces) proved fatal to the vines. In a warmer, drier, more shallow soil a dose of 90 c. c. per vine, similarly placed, proved fatal. After considerable rain, when the ground was quite wet, a vine withstood 260 c. c. of carbon bisulphid, and some vines are said to have withstood 400 c. c.

Conditions favorable to treatment.—The treatment should never be applied for some time after plowing or cultivating, as a firm, compact, moist surface is much more favorable to the retention of the vapor.

For the same reason about fifteen days should be allowed after treatment before cultivation is resumed. If the soil is either very wet or very dry, treatment should be withheld. To be in the most favorable condition for treatment, the soil should be quite moist and moderately permeable, with a firm, even surface, well compacted by rain and having a depth of at least 8 inches.

Extent of diffusion.—The extent of diffusion of the vapor determines the distance apart at which the injections must be made in order to reach all parts of the soil evenly and effectively. This varies considerably with the amount of the dose, the temperature and humidity of the soil, and other conditions. It has been found more satisfactory to employ smaller and more frequent doses rather than a few large ones. A dose of 5 or 6 grams ($\frac{1}{5}$ to $\frac{1}{4}$ ounce) is believed to be thoroughly effective through a radius of from 12 to 20 inches, though it may penetrate much farther than that. The general rule is to make 3 injections per square meter ($1\frac{1}{5}$ square yards, nearly) in light soils and 4 injections in heavy soils. The arrangement of the holes must necessarily vary more or less, according to the system of planting. They should be at regular intervals, however, so as to cover the ground evenly, and never nearer than 1 foot to the base of the vine. It must be remembered that to be effective all the ground must be treated, and not merely those places where the presence of the enemy is proven by its injuries.

Repeated treatment.—On account of the liability of injuring the vines it has been found best to make the treatment in two small applications, separated by an interval of from six to ten days. This decreases the density of the vapor, but continues its action for a much longer time. It removes the danger of injuring the vines, and gives even better results upon the insects than would be obtained by one large dose. The total amount of carbon bisulphid to be used should be divided into as many equal parts as there are injections to be made. The holes for the second treatment should be intermediate between those for the first.

Depth of the holes.—The depth of the holes depends somewhat upon the depth and permeability of the soil, the average depth being about 1 foot. A depth of 16 inches is desirable upon deep or very permeable soil.

Season of application.—Treatment may be applied at any season of the year; but, as it is followed by a slight check in growth, it should not be applied either at the flowering or fruiting season, as the check would injure the crop most at those seasons. The injury to the vines results from the killing of the tender, fibrous, feeding roots. It would therefore be better to apply the treatment before these roots have started much—that is, early in spring—or after they have become hardened that is, after fruitage in the fall. The condition of the soil usually favors the spring treatment, and the condition of the insect is

said to make it more susceptible at that time. Spring, therefore, appears to be the most favorable season.

Amount to use per acre.—Two entirely different objects may be had in treatment: First, to stamp out entirely and surely all traces of the pest upon its first appearance in a vineyard, or when desiring to reset, regardless of the life of the vines; second, to control the pest in such a way as to prevent its multiplication while continuing the culture of the vineyard. The first is called the extinction treatment; the second, cultural treatment. The method of application is the same in each case, but the amount of the dose differs. To secure extinction, it is usual to apply about 300 grams (10 ounces, nearly) per vine, using 150 grams in each of two applications ten or twelve days apart. This is said to kill ninety-nine out of every hundred vines. In cultural treatment the amount of the liquid to be used varies, according to the conditions previously described, from 140 to 265 pounds per acre.

Instruments for application.—One of the principal difficulties in the first use of carbon bisulphid was to force the vapors to the desired depth. When first used below the surface, it was poured into holes formed by driving an iron bar with a maul. The demand for a more convenient, accurate, and rapid working instrument was soon met by the invention of the pal-injector by M. Gastine. This instrument was later improved by M. Vermorel, and it fills the need admirably. The carbon bisulphid is placed in a large chamber, from which an outlet leads down through a series of valves, so adjusted that the amount of each discharge can be exactly regulated as desired, and opens near the tip of a pointed bar. The instrument is forced into the ground by the handle and the pressure of the foot upon a spur to a depth of about 1 foot; the central plunger is then pressed down and the desired amount of the liquid is discharged; the instrument is withdrawn, and the hole closed with the foot, or, as is usual in extensive work, another workman follows with a rammer, with which the holes are closed and the soil at the same time is firmly compacted. It is said that two men working together in this way can make between 2,000 and 3,000 injections per day. One acre will require on the average from 10,000 to 12,000 holes.

Plows have been invented which facilitate considerably the application, but it can not be made as deeply as with the injectors, on account of the interference of the roots. If such a plow is used, about one-fourth to one-third more of the carbon bisulphid will be required, on account of its nearness to the surface. The liquid is ejected from the machine with so much force that it becomes separated into fine drops, thus facilitating rapid evaporation. Soil is then drawn up over the liquid and compacted by the machine. Slight explosions occasionally are produced during application, especially in stony soils, by sparks caused by the steel striking against stones, but they are by no means serious.

Retarding evaporation.—Mixtures of carbon bisulphid with other substances designed to retard evaporation have been made, and the pure liquid has been used by putting it up in gelatin capsules, which allow a slow evaporation; but as these methods have not given as good results as the use of the pure liquid they will not be discussed in detail.

Many of the foregoing statements regarding the treatment of Phylloxera apply equally well to the treatment of other insects living underground.

TREATMENT FOR ROOT MAGGOTS.

Carbon bisulphid has been more or less successfully used for the cabbage root-maggot ever since 1880, when Prof. A. J. Cook experimented with it with such success that he began to recommend it. There is no doubt that its efficacy varies considerably with the nature of the soil, and there is equally little doubt that many of the failures which have been reported in its use have been due very largely to improper or too tardy application. If the liquid comes in contact with the roots, it will undoubtedly prove fatal to the plant, but a considerable amount of the vapor will do no harm. If the remedy is delayed until the plants are badly wilted, it is very likely that they will not recover, even though the enemy be killed, but their death can not fairly be attributed to the carbon bisulphid. Some growers who have tested it thoroughly state that it will work on clay or sand without injuring the plants. It has been found fatal to the pupæ as well as the larvæ. Mr. M. V. Slingerland, of the Cornell University Agricultural Experiment Station, investigated the subject in 1894[1] and his "experiments demonstrated that when properly applied the substance was sure death to the insects and did not injure the plants."

McGowen injector.—Some instrument was needed to facilitate its application, as the French pal-injectors are too heavy and too expensive. To fill this need, the McGowen injector was produced. This very convenient little instrument could be adapted to nearly all of our uses of carbon bisulphid for underground insects, but the writer has been informed by Mr. McGowen that the demand for it has been so small that he has discontinued its manufacture.

Method of application.—Whatever the instrument used, the treatment should be made in practically the same way. The hole should start 3 or 4 inches from the stem of the plant and run down obliquely to a point a little below the roots, where the liquid is deposited. The hole is then closed with earth and compacted by pressure of the foot. The dose required varies from a teaspoonful for each small plant to a tablespsoonful for large plants (4 teaspoonfuls=1 tablespoonful=1 fluid ounce approximately). One injection will be sufficient if made in time, but if delayed too long nothing can save the plant. The conditions of

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[1] See Bul. No. 78, Cornell University Experiment Station.

the soil noted under Phylloxera treatment will have practically the same influence in this case.

There appears to be no reason why a similar method of treatment may not be equally effective against such other insects as the grape root-worm (*Fidia viticida*) and the peach borer (*Sanninoidea exitiosa*), especially on young trees, where the borer usually works just beneath the surface of the ground.

DESTRUCTION OF ANTS.

Carbon bisulphid is the best remedy known for the destruction of ants, which are frequently great nuisances to farmers and gardeners. With a little careful observation most of the common house ants, except the little red house ants, can usually be traced to their homes out of doors. The only effectual way of stopping the annoyance or injury from these insects is to destroy the queens living in the nests which they never leave.

Method of treatment.—The treatment consists in making one or more holes in the nest with a stick or iron bar to the depth of from 1 to 2 feet, and pouring into each hole 1 or 2 ounces of carbon bisulphid. The hole may be closed immediately by stepping on it; or, as many writers suggest, the vapor may be exploded at the mouth of the hole with a match, in order to drive the fumes deeper into the chambers. If the latter method is adopted, the hole should be covered with fresh earth immediately after the explosion, in order to put out the fire and confine the fumes. If this is not done, a large portion of the gas will be burned and the efficiency of the treatment be lessened thereby. Right at this point an added word of caution must be given. After the explosion the vapor continues to burn with a colorless flame. It is therefore invisible, but its presence may be easily perceived by holding the hand over the opening or by blowing into it. This point should be carefully noted, for if the operator, thinking the fire had ceased and desiring to make the extermination of the insects doubly certain, should attempt to recharge the hole from a can or bottle an explosion would surely follow, with possibly fatal results. Explosion does not appear to add to the efficacy of the treatment and is not at all necessary. If it is not attempted, it may be well to cover the nest with a wet blanket, which will aid greatly in confining the fumes. If any considerable area is infested, as is often the case in lawns, the holes should not be more than 1½ feet apart each way, and, after the close of the application the surface treated may be thoroughly watered, as the wet surface will add to the efficiency of the treatment by preventing the rapid diffusion of the fumes into the air.

USE AGAINST WHITE GRUBS AND MOLE CRICKETS.

The same method of treatment which has just been described for use against ants infesting considerable areas in lawns will apply

equally well to the above-named insects. One ounce per square yard divided among three or four injections should give very satisfactory results. The life cycle of these insects occupies three years. The eggs are laid about June, and the young larvæ feed very close to the surface until cold weather comes on, then all go down to a considerable depth to spend the winter. The most favorable time for the treatment of these pests is after they descend in the fall and before they come up again in the spring. If treatment is made in midsummer, many of the small insects are so near the surface that they will escape, owing to the ready dilution of the vapors by the air. If the soil is fairly permeable and at least 8 inches in depth, a careful treatment should be successful and the ravages of the insects for three years will be prevented by one operation.

OTHER SUBTERRANEAN USES.

The vapor of carbon bisulphid applied at the rates previously recommended is said to have a marked action against certain cryptogamic parasites of plants, though its influence in this direction does not appear to have been much studied. It is also said to be fatal to the nematode worms, which are frequently injurious. In greenhouses these would seem to be particularly susceptible to effective treatment. The vapor of carbon bisulphid is fatal to animal life of all forms if inhaled in sufficient quantity. Within recent years this chemical has come into quite extensive and successful use against a class of small mammals which are common nuisances, if not actual pests, in many parts of the country, and particularly in the West. To Prof. E. W. Hilgard, of the University of California, is given the credit of being the first to employ this remedy against ground squirrels and gophers.[1] It is a matter of common knowledge that this agent is by far the safest and most efficient known for the destruction of prairie dogs, gophers, pocket gophers, ground squirrels, woodchucks, moles, and other pests having similar burrowing habits. The subject is quite an extensive one, and as it is now being given consideration by the Division of Biological Survey, and does not properly come within the province of the Division of Entomology, further comments here are unnecessary.

DESTROYING BORERS IN TRUNKS OF TREES.

Considerable has been written in favor of this use of carbon bisulphid. It is apparent that only the large borers which work in the trunks and lower branches of trees will be good subjects for this treatment. There are usually but few of these in each trunk, and the outlets of such burrows as contain active borers are usually marked by the sawdust and castings which the borers throw out therefrom.

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[1] Bul. 32, Univ. Cal., "On the Destruction of the Ground Squirrel by the use of Bisulphide of Carbon," 1878.

Only these burrows should be treated. Clean-cut empty holes in the trunk indicate that the insect has become adult and left the tree. It is, therefore, a useless waste to inject the liquid into such holes. In peach, plum, apricot, and cherry trees (all stone fruits), an abundant exudation of sap through the outlet of the burrow causes a ball of gum, mixed with castings, to collect around the hole. This should be scraped off before the treatment is applied.

Method of treatment.—Having cleaned out the mouth of the hole as well as possible, inject a small quantity of carbon bisulphid and close the hole tightly with a little grafting wax. This will quickly kill the borer and will not injure the tree; it also saves the additional injury which would necessarily be made in cutting out the borer. The saving of time alone will fully pay for the small amount of carbon bisulphid required. The liquid may be conveniently applied by means of a spring-bottomed oil can.

DESTROYING SUCKING INSECTS UPON SMALL PLANTS.

The principal pests included in this group are such insects as plant-lice, which frequently damage melon and squash vines. "The treatment, as successfully practiced by Professors Garman and Smith, consists in covering the young vines with small tight boxes, 12 to 18 inches in diameter, of either wood or paper, and introducing under each box a saucer containing one or two teaspoonfuls (1 or 2 drams) of the bisulphid. The vines of older plants may be wrapped about the hill and gathered in under larger boxes or tubs, and a greater, but proportional amount of bisulphid used. The covering should be left over the plants for three-quarters of an hour to an hour, and with 50 to 100 boxes a field may be treated with comparative rapidity."

A slight improvement upon the foregoing method of introducing the bisulphid is to bore a hole about 1 inch in diameter in the middle of the top of each box. Under this hole, inside the box, fix a small bunch of cotton waste, rags, or almost any absorbent material capable of taking up somewhat more liquid than it is intended to use; fit a stopper to the hole outside and the box is ready for use. Place it over the plant, being careful to see that the edges set into the dirt all around; remove the stopper; pour in the desired amount of liquid; replace the stopper and leave the vapor to do its work. This obviates the necessity for saucers and saves the trouble of handling more than one thing when moving from vine to vine. The carbon bisulphid might be easily carried in, and poured from, an ordinary gallon oil can such as is used for kerosene.

TREATMENT OF STORED PRODUCTS.

Agricultural products are frequently brought together in storehouses, mills, etc., in immense quantities, and, when allowed to stand

for some time, as is often the case, become particularly favorable material for the nourishment and multiplication of a large number of insect species. To exterminate these necessitates the treatment of an entire room or building.

The fumigation of buildings.—Carbon bisulphid is used in fumigating milling establishments, warehouses, storage rooms, grain elevators, stores, houses, barns, etc., for the destruction of insects affecting stored cereals and vegetable products, manufactured food products, dried tobacco and its various products, drug-store insects, and household insects which may be sufficiently numerous or injurious to warrant such treatment. Besides being efficient for the destruction of such insects, it will also kill other animals, such as rats and mice, which it may reach. The most favorable time for application may vary somewhat, as will be shown by the individual life histories of the insects treated. It would require too much space to mention all the minor details.[1]

Preliminary investigation.—When a fumigation of this kind is undertaken, a preliminary investigation should be made which should make clear the nature of the pest, its habits, its injury, and as much of its life history as may be necessary to show whether one time will be more favorable to treatment than another. The building or room should be examined, its tightness ascertained, and its floor area and cubical contents computed. Objections to treatment and unavoidable dangers should be considered. In short all the pros and cons should be carefully weighed before treatment is determined upon.

Preparations for treatment.—The building should be made as tight as possible. If glass is out, it should be reset; doors and windows should be made to fit snugly, and a special examination should be made for cracks and leaks around the floors and lower walls. The place should be thoroughly swept and cleaned, and a coat of whitewash may sometimes be desirable. The material infested may be exposed, and, if movable, placed on the floors.

Shallow tin pans or plates make good evaporating dishes. The larger the evaporating area the better. There should be about 1 square foot of evaporating surface to every 25 square feet of floor area, and each square foot of evaporating surface should receive from one-half to 1 pound of the liquid. These figures are, of course, only suggestive and approximate. Pans should be placed as high in the room as possible, since the vapor is so heavy that it settles most heavily to the lower parts. Care should be taken when placing the pans to see that they are nearly level, so as to hold the liquid, though ordinarily no particular harm will be done if some of it is spilled. It should not be found necessary to lose time in adjusting such things after the application is begun. If there are special places which are difficult of

[1] See Farmers' Bulletin No. 45: Some Insects Injurious to Stored Grain.

access or treatment with the pans, cotton waste, bundles of rags, or the like may be saturated and thrown into these places. Everything should be done to avoid unnecessary delays and to facilitate the rapid exposure of the liquid. If the liquid is bought in large quantities, smaller receptacles may have to be provided for transferring it to the pans.

The exposure of the liquid.—As many men may assist in the exposure as can work to advantage. Before the cans or drums are opened the men should be cautioned as to the nature of the liquid, the danger from fire, and the necessity for rapid work. If more than one floor is to be treated, begin at the bottom and work upward. Carefully close and fasten all windows and outer doors except one through which exit is to be made when the operation is completed. Pour out the liquid as rapidly as may be done, giving each pan about its predetermined amount, and then get out quickly. Close the door and keep it locked for twenty-four hours at least, longer if possible. The best plan usually is to apply the liquid after work hours, but before dark, on Saturday evening, and leave the building closed till the following Monday morning.

Ventilation.—Doors and windows are then opened wide, at least one or two hours before it is time to resume work. The vapors disappear rapidly in the open air, and after an hour there will ordinarily be no danger in entering and but little trace of the disagreeable odor. Slight traces of the odor will probably linger in corners and places where the air does not move freely, but these gradually disappear.

Precautions.—Attention has been called to the dangers from fire in the presence of carbon-bisulphid vapor in the air, but special reference should be made to it in connection with the treatment of buildings. It is customary to mention the danger of bringing a lighted cigar or any such thing into the presence of the fumes. The application should always be made in daylight, as no artificial light of any kind is allowable. Even electric lights may not be used, since, when turning them on or off, there is always danger of producing a spark, which would prove disastrous if the vapor should be present in the proper proportion. Heated steam pipes constitute another danger to be guarded against, and they should be allowed to cool before the application is made. Electric fans must not be run, as they very frequently give off sparks. It is safer to have no heat of any kind in the building while the exposure is being made, and it is a matter of courtesy, as well as a precaution, to warn the owners of adjoining premises of the nature of the work being done, and the need for care if the vapors should penetrate to their rooms to any extent. It would be an added measure of safety to have a watchman to guard the premises from the time the application is made until ventilation is complete.

TREATMENT OF SEEDS.

Many kinds of grain and garden seeds are subject to the attack of insects. Contrary to the claims of many seedsmen, such insects do injure the germinating power of the seed. Even if the embryo itself escapes attack, which is by no means always the case, the supply of reserve food material upon which it depends wholly for its start in life is more or less consumed by the pest, and the vitality of the young plant is proportionally weakened thereby. The principal seeds attacked are corn, wheat, rice, pease, beans, and cowpeas, while vegetable seeds suffer more or less. Experiment has not yet shown any insecticide equal to carbon bisulphid for the destruction of all these seed insects.

Method of treatment.—Seeds designed for treatment with carbon bisulphid should be placed in barrels, bins, or rooms, care being taken especially to have the receptacle tight around the sides and bottom. The cubical contents of the receptacle should be computed and carbon bisulphid applied at the rate of from 1 to 1½ pounds for each 1,000 cubic feet of space, which is the capacity of a bin or room 10 feet each way. A barrel will require a larger proportional amount unless it is very tight. The liquid is placed on top of the seed in shallow pans or soup plates, about a teacupful being placed in each. A small bin or barrel may be covered sufficiently tight with heavy blankets or oilcloth. The receptacle should be kept tighly closed from twenty-four to thirty-six hours with perfect assurance that the germinating power of the seed will not be injured. Rye, millet, barley, and crimson clover are the most liable to injury and should receive the minimum of treatment.

Fumigation houses.—In the large seed-growing districts special houses are constructed for this work. The following description of the house and the manner of treatment is given by Prof. A. J. Cook:[1]

> The house is made air-tight; even the door is made very close fitting, and it is made still closer by pasting paper over the edges upon closing it, after filling the house with sacks of peas. An air-tight flue at one end opens at the very top into the building and at the bottom out of doors. A sort of shoot with an adjustable air-tight valve is arranged for the turning in of the liquid. The liquid is turned in till the odor shows that the vapor is pouring out at the bottom of the flue. Then, of course, the air has been all forced out by the vapor, when the valve is closed. It is left closed for three days; then the doors are opened, that the vapor may escape, when all the weevils will be dead.

As a rule, seed pests enter the seeds in the field. Treatment is therefore most effective if made as soon as possible after harvesting.

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[1] In Bulletin No. 58, Michigan Agricultural Experiment Station.

TREATMENT FOR CLOTHES MOTHS.

The various insects which infest clothing, furs, etc., may be more conveniently and surely destroyed by an application of carbon bisulphid than by anything else. Moth balls, camphor, etc., may do some good by deterring the females from depositing their eggs upon articles treated therewith, but they have no killing power whatever; and if the eggs have already been deposited, the young larvæ will feed after hatching as though there were no moth balls or camphor present. Carbon bisulphid, however, will not only keep the adults away, but it will also destroy all stages of the pest infesting the goods. When woolens, furs, and the like are stored away for the summer they may be placed in a tight, paper-lined trunk, a large packing box, or some such receptacle. When all are stored away, place on top a shallow dish holding a few ounces of the liquid, spread some newspapers over the top, and cover tightly. If the box is tight, no further attention will be required; but if not, it will insure safety to repeat the dose every few weeks through the hot weather. It is an excellent plan to provide a large, tight packing chest having a close-fitting cover. Bore a hole through the cover and fasten a small sponge, bunch of cotton waste, or some such thing on the inside. The chest may then be kept tightly closed and carbon bisulphid may be poured through the hole upon the absorbent as may be necessary. Plug the hole with a cork, and all is secure. The cost of such an arrangement will very soon be saved by the convenience and security of the protection thus afforded. Carpets, rugs, robes, etc., can be easily rid of all pests by a few days' inclosure in such a box. The disagreeable odor is much less persistent in the goods than is that of moth balls or tarred paper. If pure carbon bisulphid is used it will not stain or injure the most delicate articles.

USE AGAINST OTHER HOUSEHOLD INSECTS.

Among the many insects which often abound in houses there appear to be very few which are not amenable to successful treatment in the manner already described for buildings. Cockroaches, croton bugs, bedbugs, fleas, carpet beetles, etc., can all be destroyed in tight rooms by a liberal use of the liquid. The holds of ships are frequently cleared of pests in this manner.

DESTROYING MUSEUM PESTS.

Carbon bisulphid is quite generally used for the destruction of a number of insect pests which are included under this heading. Specimens are nearly always inclosed in fairly tight showcases or trays and can be very rapidly treated by inserting the necessary amount of liquid and closing the doors or replacing the covers. In many museums a general annual treatment is given as a measure of safety, even though no enemy is known to be present.

INCIDENTAL EFFECTS OF TREATMENT WITH CARBON BISULPHID.

EFFECT OF THE VAPOR UPON PLANTS.

In using carbon bisulphid against the grape phylloxera in France, it was soon learned that direct contact of the liquid with the roots will always prove fatal to the plant, but that roots will withstand a considerable amount of the vapor without injury. The difference between the minimum of vapor which will destroy the insects and the maximum amount which can be used without injury to the plant constitutes the range of usefulness of this insecticide. Extensive experiments were made by two French investigators. Their first experiments were made by treating two series of plants, the first with varying amounts of carbon bisulphid emulsified in water, the second with the same amounts without the water. The results showed that the water moderated the action of the liquid. Succeeding experiments confirmed this result and also showed that different plants possessed different powers of resistance to the insecticide. The moderating influence of the water was doubtless due to its having increased the humidity of the soil, which, as previously stated, would retard evaporation and diffusion. Of all the plants tried, the grape appeared the most resistant. Strong, vigorous vines will also resist heavier doses than will vines enfeebled by insects or disease.

INFLUENCE UPON THE GROWTH OF CROPS.

As a general rule, the crops grown upon soil treated with carbon bisulphid are very good. This fact suggests several questions: Is the vapor itself a vegetable excitant? Does it produce chemical decompositions which render more assimilable certain nutritive elements already present in the soil? Has it some particular effect upon the humus? Or is its benefit wholly due to the destruction of the lower plant and animal organisms which, living in the soil upon the roots of the plants, steal nourishment therefrom and thus weaken the vitality of their host? None of these questions seems to have been satisfactorily answered. However, it is an acknowledged fact that the growth following treatment is unusually good, and the few records which we find indicate that the increase is considerable. Treatment of a cornfield yielded an increase of 46.8 per cent in the grain and 21.73 per cent in the stover. Potatoes showed an increase in weight varying from 5.3 per cent to 38.7 per cent. In a series of experiments upon corn, oats, beets, potatoes, and clover, much the same results were obtained, but, strange as it may seem, the most marked increase was in the clover. It was found that the vapor was not detrimental to the active bacteria causing the nodules upon the roots of this legume, but rather seemed to favor their multiplication. Furthermore, it was found upon these same plats that the beneficent influence of the treatment

was quite apparent the following year, though less marked than it had been the first year.

EFFECT UPON GERMINATION OF SEEDS.

Extensive experiments[1] were conducted by the Division of Botany, United States Department of Agriculture, upon fifty-four different varieties of seeds, including the principal grain and garden seeds affected in this way. Every precaution was taken to insure uniformity in the seeds of each lot, treated and untreated. The treated lots were exposed to an atmosphere saturated with carbon bisulphid vapor for forty-eight hours. Then these seeds and those untreated were germinated and the results tabulated. Under this extreme treatment, the severity of which would never be equaled in practice, a majority of the varieties tested showed no injury, germination being practically the same in each lot. The seeds of the grass family appeared more tender than other kinds, and some of them suffered serious damage. All varieties injured in this first treatment were then subjected to a second experiment in which they were exposed for twenty-four hours to a saturated atmosphere. Many of the varieties previously injured now showed no injury at all, and the injury was markedly decreased in all cases.

Experiments were then made upon grain in bulk, using the liquid at the rate of 1 pound to 100 bushels of grain, the rate which is usually recommended, the exposure lasting for twenty-four hours. In this case no difference could be detected in even the most delicate seeds.

EFFECT UPON FOOD STUFFS, ETC.

According to the testimony of a large number who have used this insecticide in flouring mills, food stores, and like places, the vapor has absolutely no injurious effect upon any food stuff. If the liquid is pure it can even be poured upon such articles, and after thorough exposure to the air not the slightest trace of it will remain. Of course, with impure grades, the liquid should not be poured upon such things, because the excess of sulphur and other impurities therein contained are not volatile, and upon evaporation will be left behind. It is certain that no trace of the vapor which would be absorbed by flour during an exposure thereto could persist through the processes of cooking so as to appear in the food. Owing to the extreme volatility of all the vapors given off even by the impure liquid, they will all be driven out of the flour or dough through the processes of mixing and baking. It can be positively stated that no food stuff has yet been found to be at all injured by an exposure to the vapor of carbon bisulphid.

It is believed that it would be a wise investment to give all mills,

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[1] Circular 11 of Division of Botany.

warehouses, and stores where grains, flour, or any food stuffs are kept a thorough annual cleaning, followed by an application of bisulphid sometime in early spring. Much if not all this insect injury would thus be avoided and the purity and cleanliness of food materials would be more fully insured.

EFFECT OF THE VAPOR UPON FRUIT.

It has already been stated that the vapor of carbon bisulphid acts as a powerful disinfectant, having the power to preserve meats unchanged for a considerable time. Very recently an Italian, M. F. Sestini, has experimented to determine its effect upon fresh fruits. The substance of his conclusions is as follows:

1. One volume of carbon bisulphid evaporated in 10,000 volumes of air produces no alteration in the character of the fruit during an exposure lasting twenty-four hours. After the treatment flavor is normal and it appears that the perfume of each fruit gains in fineness and intensity.

2. With this dose of carbon bisulphid all the common insects are easily killed in one hour.

3. Under these same conditions the color of the fruits which are not entirely sound becomes deeper, especially upon those parts of their surfaces which have suffered bruises during ripening or from defects in packing; it is thus very easy to choose carefully, rejecting such fruit as could not have been preserved.

APPENDIX.

CHEMICAL EXPERIMENTS WITH CARBON BISULPHID.

The chemical symbol of carbon bisulphid is CS_2. Its molecules consist of one atom of carbon united with two atoms of sulphur. The specific gravity of the liquid is 1.29. The vapor is 2.63 times as heavy as atmospheric air. The pure article volatilizes rapidly and completely when exposed to the air. The liquid boils at 115° F.

The vapor takes fire in air at about 300° F. and burns with a faint blue flame, with difficulty visible in daylight, but evolving considerable heat and decomposing the carbon bisulphid into carbon dioxide (CO_2) and sulphur dioxide (SO_2). The latter is the familiar gas given off by the burning of sulphur matches and is a strongly poisonous suffocating gas, which should not be inhaled. Carbon bisulphid vapor mixed with three times its volume of oxygen, or an amount of air containing that amount of oxygen, forms a mixture which is very highly explosive upon ignition. As 21 per cent of the air is oxygen, one volume of liquid carbon bisulphid evaporated in 5,357 volumes of air would form such a mixture. An atmosphere composed of one volume of carbon bisulphid vapor to approximately 14.3 volumes of air is liable to violent explosion in the presence of fire of any kind whatever, or a temperature of about 300° F. without flame. We have here about the maximum danger point from explosion in the use of carbon bisulphid.

At the suggestion of the writer, the Division of Entomology requested information from the Bureau of Chemistry of the Department of Agriculture on the following points:

(1) Minimum proportional volume of carbon bisulphid vapor inflammable in air.

(2) Minimum proportional volume producing an evident explosion.

(3) Proportion producing most violent explosion and how violent.

(4) Maximum proportional volume giving any explosion.

(5) Temperature of ignition point.

(6) Relative volume of vapor given by evaporation of one volume of liquid carbon bisulphid.

(7) The proportion of vapor of carbon bisulphid in a saturated atmosphere.

(8) The proportion of vapor produced in 1,000 cubic feet of air by the evaporation of 1 pound of carbon bisulphid.

The following is abridged from the report prepared in response to this request in the Bureau of Chemistry by Mr. E. E. Ewell.

AMOUNT OF CARBON BISULPHID IN A SATURATED ATMOSPHERE.

Several factors affect this quantity, but the principal one is temperature. Beginning at the freezing temperature of water, 32° F., a series of calculations was made with increments of 9° F. in temperature. As will be seen by the accompanying table, the amount of carbon bisulphid taken up increases most rapidly as the highest temperature is approached.

Amount of carbon bisulphid in a saturated atmosphere at different temperatures.

Temperature.	Pounds (avoirdupois) per 1,000 cubic feet of air.
32° F. (0° C.)	35.8
41° F. (5° C.)	43.9
50° F. (10° C.)	53.5
59° F. (15° C.)	64.6
68° F. (20° C.)	77.6
77° F. (25° C.)	92.4
86° F. (30° C.)	109.3
95° F. (35° C.)	128.6
104° F. (40° C.)	150.4

In the following table are given the relative volumes of carbon bisulphid vapor and air in 100 volumes of an atmosphere saturated with vapor at the temperature named and at standard atmospheric pressure:

Relative volumes of CS_2 vapor and air in 100 volumes of a saturated atmosphere (reduced to standard atmospheric pressure) at various temperatures.

Temperature.	Volume of CS_2 vapor.	Volume of air.
32° F. (0° C.)	16.8	83.2
41° F. (5° C.)	21.1	78.9
50° F. (10° C.)	26.1	73.9
59° F. (15° C.)	32.1	67.9
68° F. (20° C.)	39.2	60.8
77° F. (25° C,)	47.5	52.5
86° F. (30° C.)	57.2	42.8
95° F. (35° C.)	68.4	31.6
104° F. (40° C.)	81.3	18.7

INFLAMMABILITY AND EXPLOSIVENESS OF CARBON BISULPHID VAPOR WITH AIR.

Three series of experiments (two with chemically pure carbon bisulphid, and one with "fuma" carbon bisulphid) were made to determine the inflammability of mixtures of carbon bisulphid (CS_2) vapor with air, and to determine the mixtures which are explosive and the violence of the explosion which takes place when these mixtures are brought in contact with a gas flame.

For the first series an atmosphere saturated with carbon bisulphid (CS_2) vapor at about 72° F. was prepared. Portions of this saturated atmosphere were transferred to graduated tubes in which it was allowed to mix with varying amounts of air. Ten tubes were prepared in this way, the percentage of the saturated air in the mixture being increased from the first to the tenth. In column 1 of the following table is given the percentage of air saturated with CS_2 vapor at 72° F. used in the mixture in each tube. In column 2 of the table the quantity of carbon bisulphid (grams per liter) in each is stated. In column 3 of the table is given a statement in regard to the degree of inflammability or explosiveness of each of the mixtures:

Inflammability of mixtures of CS_2 with the air.

Per cent of saturated air in mixture.	Grams[a] of liquid CS_2 per liter of the mixture.	Inflammability.
5	0.068	Barely inflammable.
10	.135	Inflammable; very slight explosion.
20	.270	Burns with slight explosion.
30	.405	Distinctly stronger explosion.
40	.540	Slight explosion.
50	.675	Mild explosion.
60	.810	Do.
70	.945	Burns almost quietly; slight explosion.
80	1.080	Burns almost quietly; very slight explosion.
100	1.350	Burns quietly.

[a] One pound per 1,000 cubic feet equals 0.016 gram per liter.

It is to be noted that the explosion which occurred was not violent in any case. The strongest explosions occurred with mixtures containing from 20 to 60 volumes of air saturated with carbon bisulphid vapor at 72° F. mixed with 80 to 40 volumes, respectively, of pure air at the same temperature.

In the second series of experiments a smaller proportion of carbon bisulphid was used in three cases. Five experiments were made. The capacity of 5 bottles holding 4 liters (about 4 quarts) was obtained with approximate accuracy. For the charging of each bottle the quantity of liquid carbon bisulphid named in the following table was weighed in a small glass-stoppered weighing bottle. A string was tied to the stopper of the weighing bottle, which was then placed in the 4-liter bottle prepared to receive it. When the weighing bottle had reached the bottom of the large bottle, the stopper was removed by a sudden jerk of the string, the string was dropped in the large bottle, and it was quickly closed, the stopper being sealed in immediately with paraffin. This method of preparing the mixtures is more accurate than the one employed for the first series of experiments. The 5 bottles thus charged were allowed to stand for about three hours for the thorough diffusion of the vapor. At about the middle of this period the bottles were inverted in order to facilitate the diffusion. The stopper of each bottle was then carefully removed and a small gas jet burning at the end of a glass tube was inserted in the bottle. The results obtained are indicated in the following table:

Inflammability of mixtures of CS_2 with the air.

Bottle No.	Wt. CS_2 per liter.	Wt. CS_2 per 1,000 cubic feet.	Inflammability.
	Grams.	*Pounds.*	
1	0.0075	0.47	Not inflammable; slight odor of sulphur dioxid after removal of gas jet.
2	.0182	1.14	No general combustion; a very small blue mantle of burning carbon bisulphid formed around the gas jet.
3	.0461	2.88	No general combustion; blue mantle of burning carbon bisulphid formed around gas jet.
4	.0805	5.02	Inflammable.
5	.1552	9.68	Very inflammable; very slight explosion.

There was no general combustion except in the case of bottles Nos. 4 and 5. In the case of bottles Nos. 3 and 4 the result was very interesting. The mixture of the vapor with air was so dilute that the small gas jet introduced did not heat it hot enough to cause a general combustion, but a zone of combustion extended around the gas jet in every direction in the form of a blue mantle. It is worthy of note that the proportion of carbon bisulphid used in No. 3 (2.88 pounds per 1,000 cubic feet) is more than is ordinarily used in the fumigation of buildings. It must be remembered, however, that when small proportions of carbon bisulphid are used, the quantity in the air near the vessel containing it may be sufficient to cause an explosion if a flame is brought near it, or if the mixture be sufficiently heated by any other means.

The experiments reported above were made with chemically pure carbon bisulphid. The third series of experiments described below was made with the commercial carbon bisulphid known in the market as "fuma," which is largely used as an insecticide. As a comparison of the results will show, the inflammability of this commercial grade of carbon bisulphid is not essentially different from that of the chemically pure substance.

Inflammability of "fuma" carbon bisulphid in mixture with air.

Carbon bisulphid per liter of air.	Carbon bisulphid per 1,000 cubic feet of air.	Inflammability.
Grams.	*Pounds.*	
0.002	0.12	Not inflammable.
0.004	0.25	Not inflammable.
0.008	0.50	No general combustion; little or no mantle around gas jet plunged into the mixture.
0.016	1.0	No general combustion; small blue mantle of burning carbon bisulphid formed around gas jet.
0.032	2.0	No general combustion; large blue mantle formed around gas jet and in path of products of combustion.
0.051	3.18	No general combustion; large blue mantle formed around gas jet and in path of products of combustion.
0.084	5.24	Flame traveled slowly to the bottom of the bottle.
0.167	10.42	Very inflammable; scarcely explosive.
0.214	13.35	Very inflammable; distinct explosion.
0.238	14.85	Strong explosion.
0.356	22.21	Still stronger explosion.
0.468	29.20	Less strong explosion than next preceding mixture.
0.594	37.07	Less strong explosion than next preceding mixture.
0.764	47.67	Less strong explosion than next preceding mixture, but very inflammable.

IGNITION TEMPERATURE OF CARBON BISULPHID VAPOR.

The temperature at which the vapor ignites when mixed with air is given in chemical text-books as 300° F. Inasmuch as it is sometimes necessary or desirable to use the vapor in rooms in which there are steam pipes or other heating apparatus, it seemed desirable to confirm or redetermine its ignition point. In the experiments made in the Bureau of Chemistry it was found that the vapor could not be ignited at 296.6° F., but twice it took fire at 297.5° F. Of course all higher temperatures would ignite it. Chemically pure carbon bisulphid was used for these experiments.

Mr. C. E. Monroe in an address before the American Chemical Society says: "One of the most striking characteristics of the mixture which this vapor forms with air is its low point of ignition. The tiniest spark, a cinder after it has ceased to glow, or the striking together of two pieces of iron without sparking are sufficient to determine the ignition." In the open air the line of ignition appears to be quite close to that of the liquid itself as is stated by some writers and shown in some experiments by the author; but Dr. C. V. Riley once stated that the vapor ignites "at a great distance from the vessel containing it." In a closed space the ignition depends upon the presence of the vapor in proper proportions and may take place at almost any distance from the liquid. This explosive property of the mixture of the vapor with air is similar to that of alcohol, petroleum products, etc., though its ignition temperature is much lower. The flame extinguishes itself in a closed vessel which does not allow access to the air.

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